



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : A61L 27/54, 27/40, 29/12, 29/16, 31/12, 31/16		A1	(11) International Publication Number: WO 00/51659 (43) International Publication Date: 8 September 2000 (08.09.00)
(21) International Application Number: PCT/US00/05738 (22) International Filing Date: 3 March 2000 (03.03.00)		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(30) Priority Data: 60/122,892 5 March 1999 (05.03.99) US			
(71)(72) Applicant and Inventor: MATSON, Louis, R. [US/US]; 2227 Rookery Place, El Dorado Hills, CA 95762 (US).			
(74) Agents: FAHRLANDER, Jill, A. et al.; Michael Best & Freidrich, LLP, One South Pinckney Street, Suite 700, P.O. Box 1806, Madison, WI 53701-1806 (US).		Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

(54) Title: SURFACE-MODIFIED BIOACTIVE SURGICAL IMPLANTS SUPPRESSING TISSUE GROWTH

## (57) Abstract

Disclosed are methods or reducing undesired tissue growth adjacent to, upon, or within surgical implants. Surgical implants, especially endoprosthetic implants, are rendered bioactively suppressant by the presence of a galvanically releasable silver component and a metal more noble than silver such as gold, platinum, or rhodium, deposited on a surface of the implant, when contacted with a physiologic electrolyte, which is generally deposited as a surface coating, which provides *in vivo* a sustained release of silver ions in a concentration effective to reduce undesired tissue growth, but insufficient to cause serious damage to connective tissue.

*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

-1-

## SURFACE-MODIFIED BIOACTIVE SURGICAL IMPLANTS SUPPRESSING TISSUE GROWTH

### CROSS-REFERENCE TO RELATED APPLICATIONS

5        This application claims priority to U.S. Provisional Application Serial No. 60/122,892, filed March 5, 1999.

### STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR

### DEVELOPMENT

10        Not applicable.

### BACKGROUND OF THE INVENTION

The present invention relates to endoprosthetic implants for the human or animal body and provides methods of rendering such implants bioactively suppressant (i.e., the implants suppress undesired tissue growth adjacent to, upon 15 or within the implant).

With few exceptions, it has been the established practice for many years to select materials for the manufacture of endoprosthetic implants that induce minimal tissue response and effects, and which possess adequate mechanical 20 properties for the intended function or application of the implant. Structural materials that do not corrode *in vivo* or cause bone reabsorption are sought for use in endoprosthetic implants.

Early endoprosthetic implants were made from common metals and their alloys. Materials used for endoprosthetic implants have progressed from surgical

-2-

stainless steel used in early endoprosthetics to cobalt chromium molybdenum alloys and titanium and titanium alloys, which are commonly used today.

Other materials used in endoprosthetic implants include ceramic and carbon-based materials and certain synthetic plastics materials, such as ultrahigh 5 molecular weight polyethylene, some forms of nylon, polymethylmethacrylate, and silicone elastomers. None of these materials is entirely bioinert (i.e. 10 bioinactive) in all circumstances. An important consideration in endoprosthetic design is the identification and development of more fully inert materials to minimize or eliminate adverse *in vivo* interactions or effects. The search for such materials is ongoing.

In the early years of implant surgery, silver was employed in the manufacture of some endoprosthetic implants. For example, silver wire, silver plates and silver-plated screws were used in bone repair surgery, and tracheotomy tubes were silver plated. However, by the mid-1930's, silver and silver plated 15 implants were no longer commonly used. Silver is generally considered to be unacceptable as an implant material, particularly for orthopedic implants, because it has poor mechanical properties and it can cause connective tissue reaction and excessive subperiosteal bone growth.

Surgical implants rendered antimicrobial by the presence of a bioerodible 20 metallic silver component on or within the implant were disclosed in U.S. Patent No. 4,615,705, which is incorporated by reference herein. In order for the metallic silver to be effective in reducing microbial growth, the silver must be activated to provide a sustained release of silver ions *in vivo* in a concentration sufficient to provide a localized antimicrobial effect without causing connective tissue damage.

-3-

The silver is activated or made bioerodible by heating the silver component or by treating the silver component with hydrogen peroxide, which results in the formation of silver oxides.

Silver-impregnated catheters have been used to reduce the risk of infection 5 associated with central venous catheters. However, experience with tunneled catheter placement suggests that positioning a silver impregnated Dacron cuff often results in unusually weak subcutaneous anchorage. Hemmerlein *et al.* hypothesized that a silver-mediated process causes an undesired decrease in fibroblast ingrowth into the cuff, thereby resulting in weak anchorage of the 10 catheter (Radiology 204:363-367, 1997). This hypothesis was supported by tests designed to evaluate the ability of the silver cuff material to inhibit the growth of cultured fibroblasts *in vitro* (Radiology 204:363-367, 1997).

In many surgical implant applications it is desirable to inhibit or minimize the ingrowth of fibroblasts and other tissues to maintain optimum functionality. 15 Surgical stents, shunts, and indwelling catheters are good examples of implants in which selectively controlled or minimal tissue ingrowth is needed.

What is needed in the art is a method for rendering an endoprosthetic implant bioactively suppressant.

20 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Not applicable.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a method of reducing undesired

postimplantation tissue growth in a human or animal subject following endoprosthetic implantation, the method comprising selecting a suitable endoprosthetic implant, wherein the implant comprises an implant structure formed of a substantially bioinert structural material, galvanically releasable silver 5 component, and at least one metal more noble than silver selected from the group consisting of gold, platinum, and rhodium, wherein the silver is deposited on at least a portion of the surface of the implant structure, and wherein the more noble metal is deposited on at least a portion of the surface of the implant structure; and implanting the implant into the subject under such conditions that a physiological 10 electrolyte contacts the silver and more noble metal.

In another aspect, the invention provides a method of rendering bioactively suppressant an endoprosthetic implant comprising an implant structure formed of a substantially bioinert structural material providing mechanical integrity to the implant, a galvanically releasable component, and at least one metal more noble 15 than silver selected from the group consisting of gold, platinum, and rhodium, wherein the silver and more noble metal is deposited on at least a portion of the implant in or on the implant structure, comprising contacting the silver and more noble metal with an electrolyte.

A further aspect of the invention is a method of forming an endoprosthetic 20 implant capable of being bioactively suppressant when contacted with a physiological electrolyte, the method comprising providing an implant structure formed of a substantially bioinert structural material, depositing galvanically releasable silver on at least a portion of the surface of the implant structure, and depositing at least one metal more noble than silver selected from the group

-5-

consisting of gold, platinum, and rhodium on at least a portion of the surface of the implant structure.

In a preferred embodiment, the galvanically releasable silver and at least one metal more noble than silver selected from the group consisting of gold, 5 platinum, and rhodium are provided as an alloy that is deposited on or in at least a portion of a bioinert structural implant material to form a bioactive suppressant endoprosthetic implant. Following suitable placement of the implant in the body, the silver is activated by the galvanic effect that occurs when a physiologic electrolyte such as blood, cerebrospinal fluid, urine, aqueous humor, synovial 10 fluid, or other body fluid contacts the silver and more noble metal of the implant.

It is an advantage that by the method of the invention, it is possible to deliver an *in vivo*, sustained release of silver ions in a concentration effective to provide a localized bioactively suppressant effect, while causing minimal connective tissue damage. In particular, the methods provide a prophylactic 15 treatment that reduces the risk of undesirable excessive postoperative tissue growth.

The composite implant formed by the method of the invention is self-contained, and it requires no external energy source (e.g., electrical current) to generate the suppressant activity. In a preferred embodiment, the activity is 20 provided by the galvanic release of silver ions. The silver ions thus produced are not accompanied by the release of excessively irritating or toxic anions, such as those generated by freely dissociable silver salts that have been used as antimicrobial agents (e.g., silver nitrate).

The method is adaptable to a variety of implant types and implantation

-6-

sites, and can be regularly employed in implant surgery. Depending on the desired and specific effect needed for any particular surgical implant, one may achieve the desired characteristics for a particular implant by selecting suitable parameters. For example, when the silver and a metal more noble than silver are supplied as an alloy, implant properties could be designed by selecting the relative percentage of metals in an alloy (e.g., silver and gold). Other parameters that may be varied include the absolute amount of silver in the implant structure, suitable implant structural material, and the site or sites at which the silver and the more noble metal is deposited on the implant.

10 Other features and advantages of the present invention will become apparent upon review of the specification.

#### DETAILED DESCRIPTION

15 Endoprosthetics are used in a variety of applications in the treatment of various disease states to promote human health. However, implantation of endoprosthetics in the body is associated with certain risks, including the infiltration and growth of fibroblasts or other undesired tissues on the implant. Colonization of an implant by fibroblasts or other cells can cause implant failure. The present invention provides methods for inhibiting or minimizing undesired 20 tissue growth adjacent to, upon, or within surgical implants.

Silver salts or especially silver oxides used in implant devices for control of bacterial infections are reported to cause undesired tissue irritation. Recently, heart valves coated with Silizone coating, a silver component included to reduce the risk of endocarditis associated with implantation, were recalled because

Silizone is suspected of placing patients receiving the valves at increased risk of paravalvular leakage (St. Jude Press Release, Jan. 24, 2000), possibly due to tissue damage caused by silver oxides.

The present invention uses silver components in implants to reduce 5 undesired tissue growth without substantially irritating or killing surrounding tissue. Reduction of fibroblast proliferation may be achieved by releasing silver ions over time in a more controlled manner than the methods used to prevent bacterial infection (i.e., release of silver ions from silver salts or oxides formed on metallic silver). The silver ions generated by the method of the invention have a 10 localized effect, and act to reduce undesired tissue growth at or near the surface of the implant where such growth is undesired.

The present invention provides a method for the sustained and controlled release of silver ions from an implant. The release of silver ions is caused by the galvanic action that results when the silver and gold, platinum, or rhodium in the 15 implant are contacted with an electrolyte. The *in vivo* production of silver ions obviates the need for activating the silver by other means (e.g., exposure to hydrogen peroxide or heating) prior to implantation.

In a preferred embodiment, silver is provided as an alloy with a more noble 20 metal, such as gold, platinum, or rhodium, and deposited on at least a portion of the endoprosthetic device by any suitable deposition means. The endoprosthetic is suitably implanted in a human or other animal, and the alloy is contacted with a physiologic electrolyte (e.g., blood or other body fluid). Upon *in vivo* exposure to a physiological electrolyte, a galvanic effect is produced, causing the release of silver ions. In an alternative embodiment, the alloy is treated by electro-explosion

to produce a powder that with a particle size of 50 nanometers or greater, which may be mixed with a semipermeable polymer capable of allowing passage of electrolytes, and deposited onto the surface of the implant.

Alternatively, the silver and the more noble metal may be distributed in a 5 particulate form in a suitable polymer coating permeable to electrolytes is deposited on at least a portion of the implant structure. It is expected that suitable molar ratios of the silver and more noble metal present in the polymer coating will be comparable to that observed for silver alloy deposited on the implant surface.

One factor that may affect the suitable ratios include the presence or absence of an 10 additional layer on the polymer layer. The distance between the silver and more noble metal particles will also affect the rate of ion release, with higher rates obtainable with greater separation between particles.

In another embodiment, the more noble metal and the silver are separately deposited at discrete locations on the implant. It is also envisioned that an implant 15 may be plated with gold, platinum, or rhodium and, using techniques known to one skilled in the art, the silver may be deposited to a selective region or regions of the implant at which tissue growth may be particularly undesired or problematic.

Depending on the requirements of a particular application, the implant can 20 be designed to release ions at various rates over longer or shorter periods of time.

In the case of an implant comprising a silver alloy, this may be accomplished by judicious selection of the ratio of silver to gold, platinum, or rhodium. An alloy having a relatively high ratio of silver to gold or platinum will have a higher rate of silver ion release compare with an alloy having a lower ratio.

-9-

The amount of silver or silver-containing material applied to the implant structure will determine the relative length of time over which ions are released. In general, the greater the amount of silver that an implant has, the greater the period of time over which silver ions will be released. When the supply of silver 5 is exhausted, the implant no longer is biologically active. The gold, platinum, or rhodium will remain as an inert, biocompatible layer.

The location of the silver or silver alloy on or within the implant may be selected with regard to the structure or intended application of the implant. In the case in which the silver or silver alloy is coated onto the implant, the coating may 10 cover the entire implant surface or only a select part or parts of the implant structure. Optionally, the silver or silver alloy may be strategically deposited over specific regions of the implant where protection against undesired tissue growth is particularly important. Alternatively, zonal tissue growth suppressant effect may be achieved by applying a corrosion mask to selected areas to prevent galvanic 15 activation and subsequent release of silver ions. Any biocompatible coating that is capable of providing dielectric isolation may be used as a corrosion mask, including, for example, Teflon or silicone. Another suitable masking material is Parylene (Paritronix, Inc.). Parylene is a biocompatible material that prevents electrolyte from passing, thereby preventing the galvanic release of silver ions.

20 Suitable means for depositing silver, a more noble metal, or silver alloy include, but are not limited to, electroplating, ion implantation, or ion beam (associated deposition). Preferably, the plated endoprosthetic is subjected to gas plasma treatment in argon gas to clean the implant prior to so as to reduce the risk of excessive tissue damage caused by residual silver oxides that may have formed

on the surface of the implant.

Optionally, the implant wall may be surface-treated before the silver, a more noble metal, or silver alloy is applied. The surface-treatment may include the interposition of an additional layer between the wall and the silver, a more noble metal, or silver alloy to increase adhesion to the implant. A thin, semi-permeable top coating of polymer, for example a polyvinyl pyrrolidone, may be applied to control release of silver ions, to improve surface smoothness, or to prevent deactivation of the silver by interfering body fluid constituents. Additionally, the polymer coating could also contain pharmaceutical agents to enhance the 5 bioactively suppressant effect or biocompatibility.

10

Conveniently, the silver component is constituted by a surface coating on at least part of the implant structure. However, the component can be constituted in other ways, for example as a deposit in one or more cavities provided in the permanent implant structure or as a permeate in a porous substrate in or on the 15 permanent implant structure.

The method of the invention is particularly suited to endoprosthetic implants having a permanent structural integrity including, but not limited to, orthopedic, ophthalmic, urological, gastroenterological, neurological, vascular, and cardiovascular implants. As used herein, the term "endoprosthetic implant" 20 may include the entire implant, parts thereof or fixing means therefor. In particular, the term includes, for example, orthopedic pins, plates, screws, artificial joints, glaucoma implants, urological stents, esophageal stents, neurological shunts, vascular shunts, indwelling catheters, anti-adhesion barriers, sutures, and cardiovascular stents.

An "implant surface" may include an exterior or interior surface. For example, catheters have an outer wall with a surface, and an inner wall with a surface that defines the lumen of the catheter.

By an implant that is "bioactively suppressant" it is meant an implant that 5 has an activity that reduces or prevents undesired tissue growth on the implant.

A material that is "substantially bioinert" as used herein is a material that is sufficiently nonreactive under the conditions in which the implant is used *in vivo* that the mechanical integrity of the implant is retained despite erosion of the metallic silver. The implant can be made of any structural material which is 10 substantially bioinert, but it is expected that materials such as titanium or titanium alloy, or cobalt chrome molybdenum alloy, or ceramic material, or nontoxic synthetic plastics material, or any combination of these materials will be particularly useful.

As shown in the Examples below, cultured mouse fibroblasts are destroyed 15 by silver release from metal pins having a silver electroplated finish on which an oxide layer was formed by exposure to hydrogen peroxide. Silver-plated pins lacking the oxide layer give a very weak or no cytotoxic effect.

Alloys comprising a range of silver to gold ratios were evaluated for 20 cytocidal activity as described below in the Examples. In the interest of expediency, bacterial cultures were employed in place of fibroblast cultures. The above mentioned alloys and other implant materials are currently being evaluated using fibroblast cultures. Comparisons between the relative effects of various types of silver on a bacterial culture can be extrapolated to fibroblast cultures because silver is biologically reactive with both bacteria and fibroblasts. The *E.*

*coli* strain employed is more sensitive to silver toxicity than fibroblasts, and in our experience, exposure to silver gives a zone of inhibition size about three or more times greater than the zone size obtained by exposing fibroblasts to the same material. In other words, a zone size of 2.5 mm with *E. coli* would correspond to a 5 zone size of approximately 0.8 mm or less using fibroblasts. Testing is currently underway to evaluate the ability of various silver and gold alloys to inhibit fibroblast growth.

Based on the results disclosed below, we have found that alloys comprising in the range of from about 50% silver and 50% gold by composition to 10 about 0.1% silver and about 99.9% gold by composition are suitable for use in the present invention, in that they confer to the implant the ability to prevent localized tissue growth without causing tissue irritation.

It should be appreciated that suitable alloys for use in the methods of the invention may include alloys of silver and any combination of gold, platinum, or 15 rhodium.

The following nonlimiting examples are intended to be purely illustrative.

## EXAMPLES

20 **Example 1 Inhibition of fibroblasts by activated silver**

A 24-hr monolayer of L-929 mouse fibroblasts cells grown at 37°C in minimal essential medium (MEM) in the presence of 5% CO<sub>2</sub> was overlaid with minimal essential medium (MEM) supplemented with serum, antibiotics, neutral red, and 2% agarose. Nitinol test pins were obtained from Shape Memory 25 Applications, Inc. (Santa Clara, CA). Three pins were electroplated with silver

-13-

(approximately 5-10 microinches thick). The silver on one of the silver plated pins was "activated" by heating in an oven at 400°F heat for 30 minutes. The silver on a second silver plated test pin was activated by contacting it with 3% hydrogen peroxide for 30 minutes. The three silver plated pins and an unplated 5 nitinol pin were placed on the solidified agar overlay on the fibroblast monolayer. The cell culture was incubated at 37° C in 5% CO<sub>2</sub> for 24 hours. The culture was macroscopically examined for evidence of cell deterioration. Any decolorized zone present was examined microscopically to confirm cell lysis.

Results showed that the unplated and the unactivated silver plated nitinol 10 pins showed no zones of lysis, indicating that cytotoxicity was undetectable. The activated silver plated pins showed a mild, but significant, 1mm zone of lysis. Additionally, suitable negative (e.g., polyethylene) and positive (e.g., latex or black rubber) controls were run, with the negative control showing no zone of lysis and the positive control showing a 5mm zone of lysis.

15                   **Example 2 Cytotoxic effects of silver alloys and activated silver**

*Escherishia coli* (ATTC 4157) was suspended in phosphate buffered saline in an amount sufficient to give a turbidity comparable to a McFarland 6 turbidity standard. A 0.1-ml aliquot of the suspension was plated and spread on standard Trypticase Soy Agar plates. The various items to be tested as described below 20 were implanted into the agar and the bacteria were incubated at 33°C for 24 hrs. The zones of inhibition were evaluated macroscopically and measured as a relative indicator of cytoidal silver activity. Results were verified by repeating the assays at least once.

Pure silver (99.999%) wire exposed to 3% hydrogen peroxide for 30

minutes was tested as described above. Inhibition zones of about 2.5 mm were formed. Unactivated pure silver wire produced a minimal zone.

Stainless steel pins were plated with various alloys containing different ratios of silver and gold. The pins were either activated by contacting with 3%  
5 hydrogen peroxide for 30 minutes or not activated, and evaluated for cytocidal activity as described above. The results are shown in Table 1.

Table 1.

Alloy (%Ag:%Au)	Activated (+/-)	Inhibition zone size (mm)
100%:0%	+	2.5
42%:58%	+	0
25%:75%	+	0
17%:83%	+	0
8%:92%	+	0
100%:0%	-	+/-
42%:58%	-	2
25%:75%	-	2
17%:83%	-	+/-
8%:92%	-	+/-

10

Initially, we were surprised to learn that activated silver in alloys comprising silver and gold are not cytocidal. However, there are several factors that may contribute to this phenomenon. The oxide that formed upon activation of the silver may have functioned as a cathode conversion mask that prevented 15 electrolyte from reaching the silver and gold corrosion cell. The amount of oxide formed may have been insufficient for detectable cytotoxicity, or the oxide formed may have been an insoluble form.

Preliminary testing comparing the relative biological effects of silver on tissue was performed indirectly using bacterial cultures. Although there is not a

-15-

known direct correlation to cytotoxicity, comparisons between the relative effects of various types of silver on bacterial culture can be extrapolated to fibroblast cultures because silver is biologically reactive with both bacteria and fibroblasts. The *E. coli* strain employed is more sensitive to silver toxicity than fibroblasts.

5 and exposure to silver gives a zone of inhibition size about three or more times greater than the zone size obtained by exposing fibroblasts to the same material. In other words, a zone size of 2.5 mm with *E. coli* roughly corresponds to a zone size of about 0.8 mm or less using fibroblasts. Testing is currently underway to evaluate the ability of various silver and gold alloys to inhibit fibroblast growth.

10 The invention is not limited to the exemplified embodiments, but is intended to encompass all such modifications and variations as come within the scope of the following claims.

## CLAIMS

It is claimed:

5        1. A method of preventing undesired postimplantation tissue growth in a human or animal subject following endoprosthetic implantation, the method comprising the steps of:

10        (a) selecting a suitable endoprosthetic implant, wherein the implant comprises an implant structure formed of a substantially bioinert structural material, a galvanically releasable silver component, and at least one metal more noble than silver selected from the group consisting of gold, rhodium, and platinum, wherein the silver is deposited on at least a portion of the surface of the implant structure, and wherein the more noble metal is deposited on at least a portion of the surface of the implant structure; and

15        (b) implanting the implant of step (a) into the subject under such conditions that a physiological electrolyte contacts the silver and the more noble metal.

20        2. The method of claim 1, wherein the silver component and more noble metal of step (a) are provided as an alloy.

25        3. The method of claim 2, wherein the concentration of silver in the alloy is effective to reduce tissue cell growth on the implant, relative to a comparable implant lacking the alloy.

4. The method of claim 2, wherein the molar ratio of silver to more noble metal in the alloy is at most about 1:1.

25        5. The method of claim 1, wherein the silver and the more noble metal are

deposited at separate sites on the implant.

6. The method of claim 1, wherein the more noble metal is deposited as a layer on at least a portion of the implant surface, and wherein the silver is zone deposited onto a portion of the more noble metal layer.

5        7. A method of rendering bioactively suppressant an endoprosthetic implant comprising an implant structure formed of a substantially bioinert structural material providing mechanical integrity to the implant, a galvanically releasable silver component, and a least one metal more noble than silver selected from the group consisting of gold, platinum, and rhodium, wherein the silver and  
10      the noble metal are deposited on at least a portion of the implant structure surface, said method comprising:

(a) contacting the silver and noble metal with a physiological electrolyte.

8. The method of claim 7, wherein the silver and noble metal are provided as an alloy.

15        9. The method of claim 8, wherein the molar ratio of silver to more noble metal in the alloy is at most about 1:1.

10. The method of claim 7, wherein the silver and the noble metal are deposited at separate sites on the implant.

11. The method of claim 7, wherein the silver is deposited on a portion of  
20      the deposited noble metal.

12. The method of claim 7, further comprising the step of:

(c) depositing a corrosion mask on a portion of the deposited silver.

13. The method of claim 7, further comprising the step of:

-18-

(c) depositing a polymer coating permeable to a physiologic electrolyte on at least a portion of the silver component.

14. A method of forming an endoprosthetic implant capable of being bioactively suppressant when contacted with a physiological electrolyte, the  
5 method comprising the steps of:

(a) providing an implant structure formed of a substantially bioinert structural material; and

(b) depositing galvanically releasable silver and a metal more noble than silver on at least a portion of the surface of the implant structure of step (a), the  
10 noble metal selected from the group consisting of gold, platinum, and rhodium.

15. The method of claim 14, wherein the silver and noble metal are provided as an alloy.

16. The method of claim 14, wherein the molar ratio of silver to the more noble metal in the alloy is at most about 1:1.

15 17. The method of claim 14, wherein the silver and the more noble metal are deposited at separate sites on the implant.

18. The method of claim 14, wherein the more noble metal is deposited as a layer on at least a portion of the implant surface, and wherein the silver is zone deposited onto a portion of the more noble metal layer.

20 19. The method of claim 14, further comprising the step of:

(c) depositing a corrosion mask on a portion of the silver.

20. The method of claim 14, further comprising the step of:

(c) depositing a polymer coating permeable to a physiologic electrolyte on at least a portion of the silver.

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 00/05738

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61L27/54 A61L27/40 A61L29/12 A61L29/16 A61L31/12  
A61L31/16

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 A61L C22C A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, FSTA, INSPEC, COMPENDEX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 886 505 A (HAYNES JOHN L ET AL) 12 December 1989 (1989-12-12)  column 2, line 62 -column 3, line 34 column 4, line 32 - line 58 column 5, line 31 - line 42 ---	1-3, 5-8, 10, 11, 14, 15, 17, 18
X	US 5 695 857 A (BURRELL ROBERT EDWARD ET AL) 9 December 1997 (1997-12-09) column 3, line 18 - line 65 column 4, line 53 - line 67 ---	1-11, 14-18
A	US 5 395 651 A (SODERVALL BILLY V ET AL) 7 March 1995 (1995-03-07)  abstract column 2, line 56 -column 3, line 27 -----	1, 5-7, 10, 11, 14, 17, 18

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

### \* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

Date of mailing of the international search report

4 July 2000

12/07/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl.  
Fax: (+31-70) 340-3016

Authorized officer

Menidjel, R

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.1

Although claims 1-6 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.

-----

Continuation of Box I.1

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/05738

Patent document cited in search report	Publication date	Patent family member(s)			Publication date
US 4886505	A 12-12-1989	AU 3155089	A	29-06-1989	
		AU 588598	B	21-09-1989	
		AU 5841786	A	11-12-1986	
		BR 8602637	A	17-11-1987	
		EP 0206024	A	30-12-1986	
		JP 2005089	B	31-01-1990	
		JP 62002947	A	08-01-1987	
US 5695857	A 09-12-1997	CA 2033107	A	25-06-1992	
		AU 669652	B	20-06-1996	
		AU 9111491	A	22-07-1992	
		WO 9211043	A	09-07-1992	
		EP 0564503	A	13-10-1993	
		JP 6503736	T	28-04-1994	
US 5395651	A 07-03-1995	US 5320908	A	14-06-1994	
		US 5965204	A	12-10-1999	
		US 5747178	A	05-05-1998	
		AT 134719	T	15-03-1996	
		AU 642872	B	04-11-1993	
		AU 5473490	A	08-11-1990	
		CA 2016081	A,C	04-11-1990	
		DE 69025495	D	04-04-1996	
		DE 69025495	T	11-07-1996	
		DK 400349	T	18-03-1996	
		EP 0400349	A	05-12-1990	
		EP 0693576	A	24-01-1996	
		ES 2086328	T	01-07-1996	
		FI 95816	B	15-12-1995	
		GR 3019899	T	31-08-1996	
		JP 2645431	B	25-08-1997	
		JP 3219085	A	26-09-1991	
		JP 8325743	A	10-12-1996	
		JP 8333687	A	17-12-1996	
		NO 304746	B	08-02-1999	

**THIS PAGE BLANK (USPTO)**